SAFETY HEADGEAR FOR MINING WORKERS USING IOT WITH ML

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Abstract. Mining is the laying of explosive mines from the earth. Mining plays a vital role in today's world due to the requirement for metals and other essential materials by accelerated urbanization and industrialization. Miners have to work at the places where there is no assurance for the safety and security, which may lead to death in some scenarios. In the mining locations there is only rapid increase of deaths but there is less scope of decreasing in deaths. According to the previous researches, the solution provided was to only find toxic gases, location tracking along with temperature monitoring and outside environment monitoring like predict the rain and floods. The observation was made that there is no real time monitoring of miners health and no information about the toxic gases is acknowledged to the miners. This paper proposes a micro controlled based circuit consists of MQ-5 gas sensor to detect harmful gases, Pulse sensor for health monitoring, GPS module for tracking miner's location and BMP-280 for temperature and atmospheric pressure monitoring are installed in the worker's helmet used to detect and alert the miners through buzzer. Using IoT devices via cloud data is transmitted to the control station. This data processed by Thing Speak cloud and displays a field graph of the transmitted data. This model uses machine learning models for weather prediction of mines. The implications of our findings extend beyond the academic realm, impacting the daily lives and well-being of miners worldwide, and reinforcing the crucial role of technology in promoting occupational safety.

Keywords: Mining Safety, Workers health, IoT technology, Hazard detection, Real-time monitoring, and Alert system, Thing Speak.

1 Introduction

The mining industry stands as a heart of modern civilization, providing the essential raw materials that fuel economic growth and development across the globe. Miners are delve deep into the Earth's crust to extract valuable minerals and resources, its play a pivotal role in sustaining industries from construction to technology. Their efforts are valuable for infrastructural development, technological innovation. Moreover, the mining industry faces ongoing critical issue of safety in mining environments, recognizing the toxic gases, and problems faced by miners due to the nature of their work. The cause of our study was to propose a unique solution to enhance miner safety through the implementation of a microcontroller-based circuit integrated into miners' helmets.

In this model, our aim was to address the critical issue of safety in mining environment, recognizing the inherent dangers faced by miners in mining industry. This microcontroller based circuit is integrated with IoT and ML including cloud for a real time monitoring. Our research sought to contribute to the creation of a safer working environment for miners, thereby improving the overall well-being and productivity of the mining industry. In terms of methodology, our paper involved the development and implementation of a smart head gear capable of detecting and controlling significant gas-related risks, such as LPG, Smoke, and CO additionally, also integrated sensors, communication protocols, data analytics, and location tracking to create a comprehensive safety system for miners.

2 LITERATURE SURVEY

[1] Yean jae Kim et al proposed a mining helmet based on proximity warning system(PWS) with Bluetooth beacon to monitor mining environment. It detect toxic gases, temperature and displays the warnings on LED to both miner and operator , using sensors and Bluetooth Low Energy signal(BLE). This system detects miner’s mental effort and stress using NASA-TLX, to enhancing miner experience and overall safety in mining environment.

[2] Sapna Patel et al introduces a smart helmet for workers safety in mining locations is integrated with gas, temperature and vibration sensors for monitoring hazards in mining. It consists of notification system in helmet and alerts the miners, facilitate immediate response activation like buzzer through the network. GPS technology is used for location tracking in mining industry in workers emergency situation. This system also enhances safety and enables real time data monitoring and safety management in mining environment.

[3] Mir Sajjad Hussain Talpur et al provides a safety system for mining industry. To improve safety from mining environment. This safety system is consisted with featured sensors and Wi-Fi communication, ESP-32 8266, arduino control board for quick response, to detect the toxic gases used gas detecting sensor. This device collects the data and provide alerts through the cloud based system. It consists of IoT technology and mobile application hence the smart helmet ensures miners safety for workers well-being.

[4] Emrah Irmak paper provides a smart life saving helmet designed to guide the need for safety mining operations. This system contains NFC tags, temperature sensor, accelerometers, Wi-Fi connectivity with new edge technology. Providing solution to the problems faced by miners such as health hazards arising out of onsite pollution

due to dust, gases, noise. This helmet provides quick emergency response , predict potential explosions also primarily aims to significantly contribute to miner's safety in mining location.

[5] T. Sowmya et al proposed smart helmet for mining workers to provide safety in hazardous environments by integrating sensor technology and communication module includes gas sensor, temperature sensor and emergency switches, it offers comprehensive detection and personal safety measures. This system also includes GSM modules and Wi-Fi modules for quick emergency response and providing GPS tracking for situational awareness underground mining. This model enhances miner's safety and creates comprehensive safety system by leveraging technology to work in a safety environment for well-being of workers.

[6] Mrs. A. Dhanalakshmi et al paper presents a safety solution for mining workers. To avoid hazards faced by miners in their work routine, they proposed a safety helmet with IoT. This helmet detect toxic gases, monitor environmental conditions such as pressure, temperature and provide alerts in the case of dangerous situations or helmet removal. This system contains PIC16F877A microcontroller including LM35 temperature sensor, force and IR sensor. These sensors work continuously to monitor the mining environment also provide the real time data to the central authority. This paper uses LabVIEW software for visualization of sensor data in the central authority system. Moreover, the system integrated with emergent technologies like IoT for enhancing and ensuring the safety solution for mining workers.

[7] B. Priyanka et al paper provides an IoT Based Smart Helmet for Mining to provide mining safety. This smart helmet integrated with sensors, wireless communication system and it continuously measures the temperature, humidity also levels of gases in mining. Utilizing the wireless communication protocols like ZigBee , the safety helmet transfers data from the mining environment to control room section, It also equipped with RF modules and GUI systems to monitor in central hub and this system enables fast responses in the case of hazardous threats . Used GSM modules and LED indicator for getting real time data and interacting with miners to provide awareness and safety. The IoT based smart helmet uses less power consumption to ensure operational longevity.

[8] B. Kartik addressed a hazards detection mechanism, to enhance safety within the mining sector by using IoT technology. This mechanism detects humidity, temperature, noisy levels and toxic gases associated with various sensors. The proposed smart helmet monitors crucial conditions in environment for mitigating risks associated with underground mining, it details each challenges such as sensor limitations and complexities associated with wireless communication in the rocky mining environment. It performance through metrics such as false alarm rate, detection accuracy, missed detection rate and response time including with the integration of emerging technologies like machine learning and sensor technology in wireless communication.

[9] Nidula Fernando et al proposed an innovative approach for miners to enhancing worker safety in the mining location. The design of smart helmet uses principles of Kansei Engineering to minimize the lives of miners annually. This proposed system equipped with Arduino Uno and sensors to monitor the mining environment such as humidity, temperature, and harmful gases like carbon monoxide and methane. The

implementation of smart helmet involves receiver and transmitter sections, receiver section placed in the control room and the data displays on LCD then activates warnings, and the transmitter section placed on helmet to detect the gases , temperature and other functionalities used various sensors like MQ 135 gas sensor, DHT11 and communication module NRF24L01.

[10] Sahil Kamble et al addressed a smart helmet for mining workers using Internet of Things(IoT) technology to provide safety in the mining industry. By integrating with different sensors such as humidity, temperature, gas and vibration sensors into the helmet, it transmits the data from the helmet to centralized station. Used ESP8266 as a microcontroller device to process the central unit within the helmet, and transmitting the data via LoRa communication modules. This collected data uploaded in the cloud and made accessible through a website, the smart helmet reducing the incidence of accidents in the mining industry.

Table 1: Comparison Table

Author Name	Hardware Components	Algorithm	Merits	Limitations
Yean jae Kim	Bluetooth beacon, Smart Helmet with LED devices.	BLE signalprocessing algorithm, Decision-making algorithm, NASA-TLX.	Collision Prevention, Visual Warnings, Adjustable Signal Detection.	Signal Range Constraints,Initial Training.
Sapna Patel	Arduino microcon troller, GPS module,Gas sensors, Temperaturesensors, GSM module, Panic switch.	Gas detection algorithm, GPS tracking algorithm, Communication algorithm.	Two-way communication, Real-time detection, Immediate notification.	Potential challenges in remote areas, Environmentalfactors.
Mir Sajjad Hussain	ESP32 Arduino,Gas detectors, Buzzer foralerting, Cloud based monitoring system.	Collision detection algorithm, WiFi-based communication algorithm.	Real-time monitoring of hazardous gases, Mobile application interface.	Wi-Fi connectivity in remote mining areas,sensor accuracy.

Emrah Irmak	NFC tags for access con-trol,Temperature sensors, Wi-Fi connectivity, Re-al-Time Operating System .	Proximity algorithm, Accelerometer data analysis algorithm, .	Access Control throughNFC tags, accurate task handling.	Initial imple-mentationcosts may be a limi-tation.
T. Sowmya	Gas sensor (MQ2), DHT11 temperature, 16x2 LCD display, GPS module.	Emergency response algorithm, Data transmission and visualization algorithm.	Comprehensive detection, Im-proved situa-tional aware-ness, On site data ac-cess throughthe LCD.	Periodic maintenance requirements for sustained effectiveness.
Mrs.A.Dhanalashmi	PIC16F877A Microcontroller, LM35 Temperature Sensor, Pressure Sensor, For ceSensor, GasSensor, IRSensor, Solenoid Valve.	Data Fusion Algorithm, Collision Pre-diction Algo-rithm.	Comprehensive Environmental Monitoring, Enhanced Haz-ard Detection.	Computational Complexity, Calibration and Synchronization, Data Fusion Errors.
B.Priyanka	Arduino Microcontrol-ler,Temperature and Humidity Sensor, Xbee, Force Sensor, Gas Sen-sor, IR Sensor, Solenoid Valve.	Decision-making algorithms, Wireless communication algorithms.	real-time monitoring, po-tential energy savings.	Requires calibration and periodic maintenance, Power consumption.
B.Kartik	GasSensor, Temperature and Hu-midity Sensor, Noise levelSensor, RFID.	Artificial intelligence algorithms, AI-driven analytics.	Proactive identification of risks, Optimization of safety protocols	Reliability concerns, Im-plementation challenges.

Nidula Fernando	Barometric Pressure Sensor, DHT22/11 DigitalTemperature Humidity Sensor, Gas Sensor, Dual band GPRSGSM SIM 800L module.	data processingand decision- making algorithms.	real-time monitoring, Integration of Kansei Engineering principles for user-centric design.	durability orrugged-ness, Potential limitations related to pow-ersource.
Sahil kamble	Microcontroller (ESP8266), LoRa communica-tionmodule, Temperature Sensor Humidity sen-sor , Gas sensor , Buzzer for alert system.	Hazard DetectionAl-gorithm, Collision. Prediction Algorithm.	Multi-sensor integration, Cloud-based data storage.	Reliance o calibration.

3 PROPOSED METHODOLOGY

The proposed system aims to provide safety for underground miners. Here the Figure-1 represents working methodology of safety headgear. This model used to detect and mitigate potential hazards in real time by integrating micro-controller based circuits into miner’s helmet equipped with sensors for detecting hazardous gases like LPG, smoke, CO also monitoring of health of miners using pulse sensor along with communication protocol data analytics and location tracking capabilities. In this methodology first step is wearing helmet, if not wear the helmet buzzer will make an alert. Later it measure the temperature, humidity and heart pulse based on requirements the data will displayed on both transmitter and receiver units.

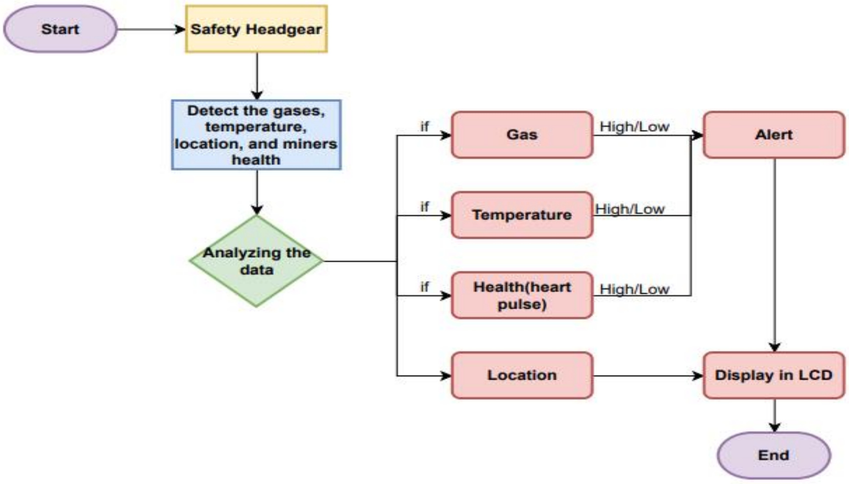


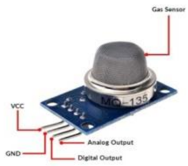
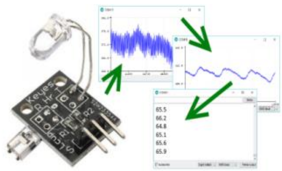
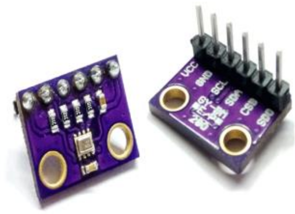
Figure 1: Proposed Methodology

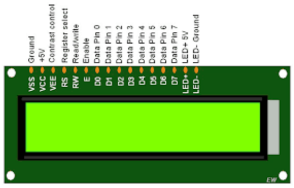
3.1 Components:

In this proposed system, to detect the gases, location, temperature, pressure, pulse needs different elements, this is achieved using IoT devices. Each device has a specific functionality which is described in Table 2.

Table 2: Comparison Table

Component Name	**Description**	**Reference**
Arduino UNO	Arduino uno is an open source microcontroller board with an ATmega328, It uses Arduino IDE (integrated development environment) for programming.	
ESP 32 Node MCU	ESP 32 Node MCU is integrated with WiFi and Bluetooth connectivity it is powerful, power efficient and cheap micro controller.	

Arduino HC 12	Arduino HC 12 is a wireless transceiver used to communicate with two micro controllers wirelessly. It is a module with 100 channels in the 443.4-473.0 MHz range.	
MQ 135	The MQ 135 is a gas detecting sensor used to detect the smoke benzene and other toxic gases. It is available for low cost.	
KY-039 Heart beat sensor	The KY-039 Heart beat sensor used to detect the human pulse using photo transistor and bright infrared (IR) LED to detect a finger's pulse with red LED.	
GY – BMP 280 Module	GY - BMP 280 Module is used to measure temperature, humidity,atmospheric pressure, and altitude accurately.	
NEO-6M GPS Module	The NEO -6M GPS Module is used to identify location anywhere in the world without having internet connection and phone signals. It can track up to 22 satellites.	

2 Pin Tactile Push Button Reset Switch	2 Pin Tactile Push Button Reset Switch is widely used input button on electronic projects, it is an easy touch and water proof also offers acute operation and long services.	
16X2 LCD Display	A 16X2 LCD Display is a electronic module having multi segment lighting. It is simply programmable, inexpensive, and has no limitations.	
Buzzer	A Buzzer is an electronic device converts audio signals to sound signals, used to various applications across industries, alarms, notifications, Its main function is to provide audible alert in the range of 5v to 12v.	

3.2 System Architecture

The safety system for mining environment, integrated with various sensors like pulse, gas, temperature, and GPS with Arduino and Microcontroller Node-MCU. Powered by a battery, it features an alert system with a buzzer and panic button. Data transmission via HC-12 Arduino facilitates real-time monitoring, with information displayed on LCD screens and stored in the cloud for website access. The Internet of Things (IoT) framework ensures prompt notification of environmental changes, enhancing worker safety. This model provides timely alerts to both on-site workers and external monitors, optimizing safety protocols in mining operations.

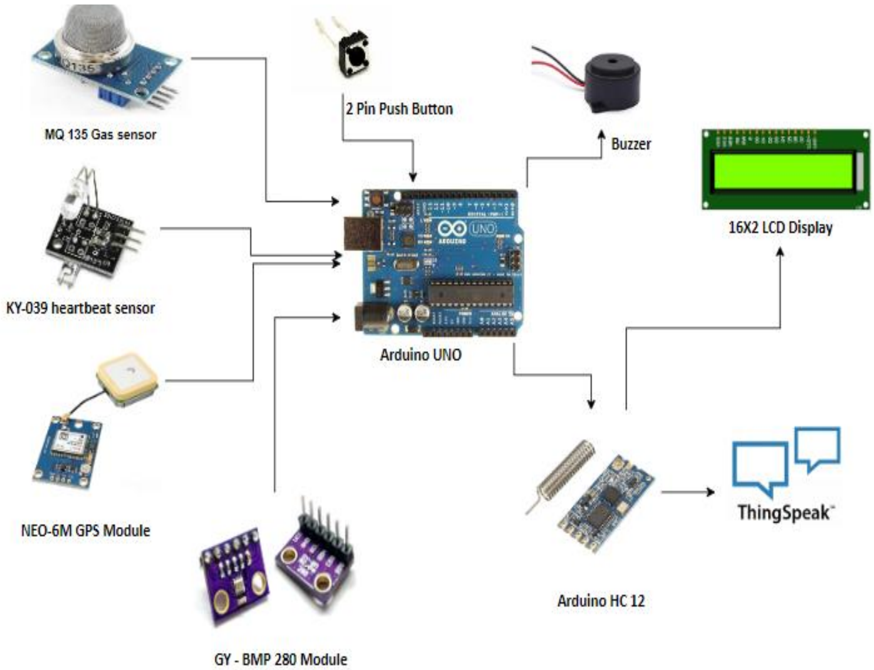


Figure 2: Block diagram for Transmitter End

Figure 2 represents the block diagram for transmitter end, consist of various sensors collects the data then send to the cloud (Thing Speak) and data will display on LCD.

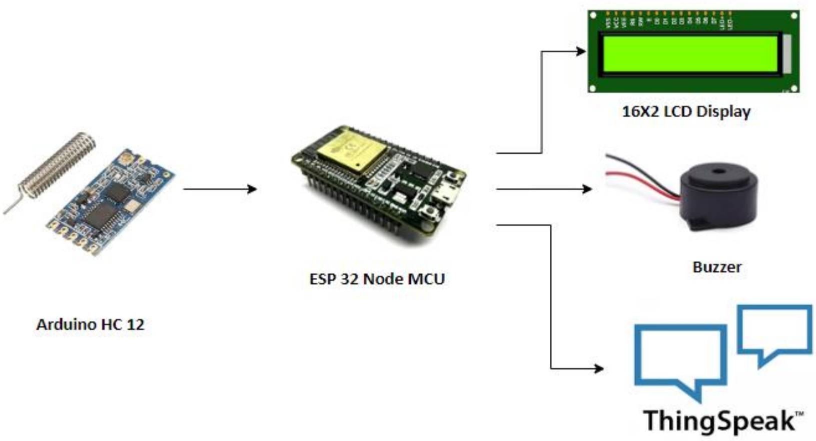


Figure 3: Block diagram for Receiver End

Figure 3 represents the block diagram for receiver end here the data receive from the Arduino HC 12 and the microcontroller will transmits into cloud and LCD, this data monitor by the control authority.

3.3 Pressure Model

A Pressure Model (PM) is a model to determine the pressures on the various sector like mining, hilly areas and tall buildings. Our Safety headgear system is integrated with IoT and ML models, datasets are must needed to implement ML models. That data is collected from the Thing Speak which stores all the sensor data in dataset. But Mining is the process of extracting metals hence this process is done under the sea level, so essential to calculate the pressure based on height , this pressure data is calculated using equation 1.

$$P(h)=760*\exp(-0.00012*h) \quad \text{–- (1)}$$

Where P(h) = atmospheric pressure values of human activities at altitude h , hPa
h = height of coal mines in mts
Typical pressure varies with respect to altitude is given below Table 3.

Table 3: Typical pressure values in different locations

Water Depth(feet of water column)	Atmospheric Pressure (atm)	Absolute Pressure (PSI)	kPa
0	1.0	14.7	101.3
33	2.0	29.4	202.7
40	2.2	32.5	224.1
140	5.2	77.0	531.2
200	7.1	103.8	715.4
500	16.2	237.3	1636.6
1200	37.4	549.1	3785.9
2000	61.6	905.3	6242.2

The pressure is depends on the various locations as well as the temperature on that site. As shown in the Table 3, the air pressure at sea level is 1,013 mbar. Air pressure is reduced to 938 mbar at an elevation of 600m. At a height of 2,000 m, the air pressure is 763 mbar only. This pressure loss is must effect on working with vacuum. This pressure drop with increasing height and also reduces the maximum pressure difference that can be attained hence the maximum holding force Per 100 m is increase in elevation, the air pressure drops about 12.5 mbar.

3.4 ML Model Approach

A Machine learning model is an intelligent file it has been conditioned with an algorithm to learn specific patterns in datasets and give predictions and insights from those patterns. Generally machine learning models are implemented through multistep process that is Data acquisition (gathering data from trusted source), Data processing(Making the data suitable for building a model), Algorithm selection(choosing an algorithm to build that model), Model building(constructing the model), Performance metrics(calculating the performance of the model), Model selection(choosing the best model).

3.4.1Need of Machine Learning Model in Mining Industry to Predicting Weather

Weather Predicting in mining industry is crucial for planning various operations, ensuring the works safety, and optimizing resource allocation. Using ML (machine learning) models can provide the esurience to the workers , this models can be trained continuously and refined with new data, also improving that accuracy and reliability over time. This is an iterative process helps mining industries to stay adaptive from changing environmental conditions. This paper used Multi Liner Regression to predicting weather.

3.4.2 Working Process of ML Model

Multi Linear Regression (MLR) is a statistical method used to represents linear relationship between a dependent variable and multiple independent variables, and it is a type of regression analysis where the goal is predict the value of a dependent variable based on the values of multiple independent variables.

Equation 2 for calculating multiple linear regression

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \ldots\ldots\ldots.. + \beta nXn \quad \text{--(2)}$$

In Equation 2 Y is the dependent variable , X1, X2, X3,…….. Xn are the independent variables , β0 is the intercept term, β1, β2, β3……….. βn are the coefficients for each independent variable and ε is the error term. Coefficients are estimated using the data and a method such as Ordinary Least Squares (OLS).

Implementation of Multi Liner Regression by using following pseudo code:

Step 1: Import the needed python packages and panda library for data manipulation, NumPy used for mathematical calculations also uses MatplotLib, and Seaborn for visualizations.

Step 2: After import the libraries load the dataset which is downloaded from the Thing speak cloud and upload it to notebook then read into the pandas dataframe.

Step 3: Now the data is ready , then analyze and understand its trend in detail. To do that first describe the data total number of samples taken from the 300 workers in mining site. The mean temperature of all 300 workers is around 27oC. The minimum temperature of all the workers are 20.31oC and the maximum is 32.35oC. Here DI index values ranges from 19.36 to 31.73, the output is 2-Uncomfort (panic button pressed), 1-Partially comfort, 0-Comfort index.

Step 4: Split the data into dependent or independent variables, Temperature & RH (%)(X) is the independent variable Discomfort Index (y) is dependent on both Temperature & RH(%).

Step 5: Now split the data into Train or test sets further, split the data into train(80%)and test(20%) sets using train_test_split.

Step 6: Train the regression model with multivariable's pass the X_train and y_train data into the regression model by regressor.fit to train the model with our training data.

Step 7: As a result, it predicts the data.

Compare results with multiple independent variables, then plot the graph to compare results visually, instead, also compare a few records of predicted results and actual values side by side. The coefficients and intercept of multiple linear regression is represent in Equation (3)

$y = \beta 0 + \beta 1x1 + \beta 2x2 + \beta 3x3 + \ldots + \beta nxn$ –(3) from the regression model. Once the coefficients are estimated, the multiple linear regression model can be used to make predictions for new data. The quality of the predictions can be evaluated using various measures such as mean Squared Error, R-Squared, adjusted R-Squared, and others.

4 RESULT AND DISCUSSION

The below receiver and transmitter unit connected individually. The LCD screen of receiver unit(Figure 4) shows the data which is transmitted from transmitter unit(Figure 5) through HC-12 Arduino. The transmitter unit is fixed on helmet of miner(Figure 6) and receiver unit fixed in the monitoring station. The data transfers from the mining location to the admin station through cloud also monitor in Thing Speak. The transmitter detects toxic gases and the parameters in transmitter unit are air quality, pulse, temperature and humidity.

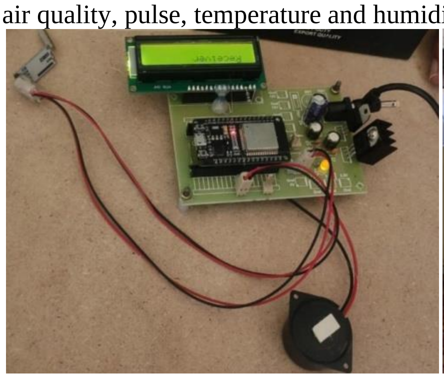


Figure 4: Receiver End

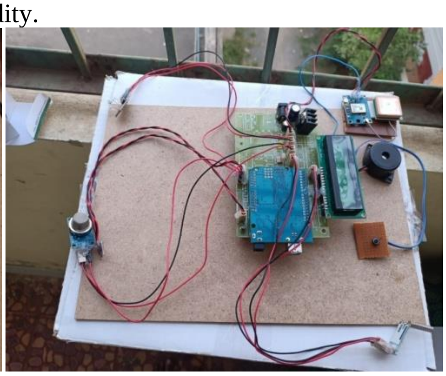


Figure 5: Transmitter Unit

Figure 6: Safety headgear with transmitter

1	Worker code	Temperature	RH(%)	Pressure P0 in (hpa)	Altitude (z)	Atmospheric Pressure (hPa)	Heat Index (HI)	Discomfort index (DI)	Output
2	L1	27.06026119	93.98%	1013	517.56804719	951.502180724715	52.3964750570396	26.6441708388709	1
3	L1	26.76906928	92.65%	1013	175.58540152	991.362139661011	51.9339310624283	26.273274265685	1
4	L1	24.62359454	75.29%	1013	376.66459983	967.727357663257	48.52134812585	23.2478994164502	1
5	L1	26.74411426	81.88%	1013	604.70979829	941.60415485349	51.8897265563993	25.5240644356876	1
6	L1	29.70521737	71.49%	1013	488.10707368	954.871995561386	56.6129259844659	27.3207274750441	1
7	L1	25.15339824	83.40%	1013	241.50949377	983.550520934623	49.3680548869786	24.1808174626434	1
8	L1	31.37457052	95.75%	1013	393.35805028	965.79073300443	59.2815252466641	30.9801720126604	2
9	L1	28.1145302	87.34%	1013	260.18135605	981.349221612361	54.071187917737	27.1664390678156	1
10	L1	24.97211417	81.20%	1013	480.80462186	955.709111096593	49.0790856904612	23.8893020164654	1
11	L1	26.53015787	81.62%	1013	432.7640347	961.234561769818	51.5497143418353	25.3140296654812	1
12	L1	29.96748238	70.93%	1013	334.21483252	972.669510709541	57.0331059353419	27.4946295302561	1
13	L1	25.73973451	93.40%	1013	419.58036718	962.756476942341	50.3039420147912	25.3320233429006	1
14	L1	28.24804095	70.83%	1013	385.00913477	966.758814496914	54.2831309155278	26.042648116876	1

Figure 7: Data collected from the sensors

Figure 7 represents the data which is collected from the different sensors and stored in Thing Speak cloud, This data set contains mining location temperature, pressure, Altitude, Heat index, Discomfort index and the output contains values like 0,1,2 here 0 represents level of comfort is good , 1 represents medium level of comfort index and 2 represents high level of discomfort index it is dangerous for miners working in mining location at the level of 2.

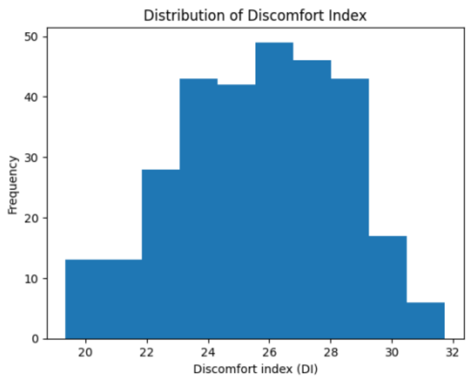


Figure 8 : Distribution Plot on Discomfort Index

Figure 8 is a dist plot or distribution plot shows the variation in the data distribution. It represents the data by combining a line with a histogram, also check the relationship between Temperature and Relative Humidity on Discomfort Index(DI) .

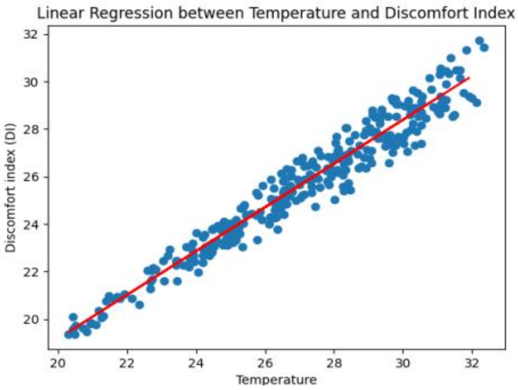


Figure 9: Linear Regression between T and DI

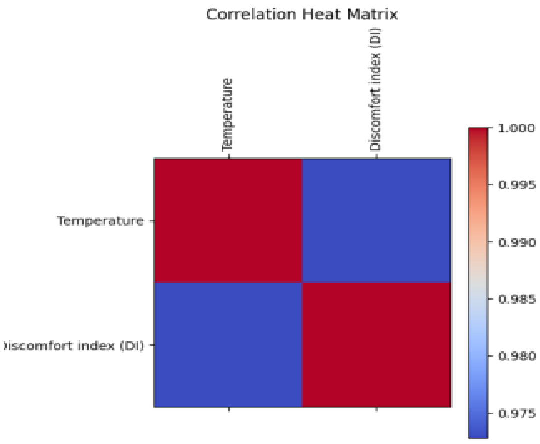


Figure 10: Correlation of Heat Matrix

From above graph, it was clearly observer the ambient temperature (T°C) is really having correlated with Discomfort Index (97.2%) when compared to other parameters. Linear Regression was built between the temperature (T) and Discomfort Index (DI) in Figure 9. And Figure 10 represents the correlation of Heat Matrix is calculated by using confusion matrix .

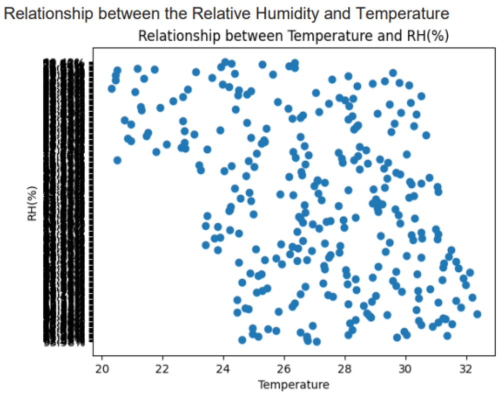


Figure 11: Relationship between T and RH

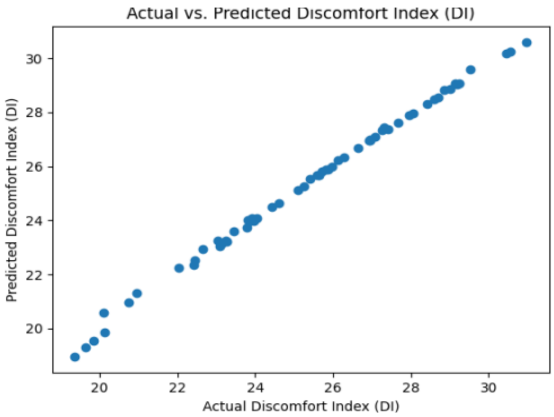


Figure 12: Predicted result and accurate values

Figure 11 is relationship between the Relative Humidity and Temperature, Split the dataset into dependent/independent variables Temperature & RH (%) (X) is the independent variable Discomfort Index (y) is dependent on both Temperature & RH(%), Further, split our data into training (80%) and test (20%) sets using train_test_split . Figure 12 is multiple independent variables, cannot plot the graph to compare results visually, instead, can compare a few records of predicted results and actual values side by Side.

Thing Speak Data Monitoring

Thing Speak is allows us to aggregate, visualize, and analyze the live data streams in cloud. It provides instant visualizations of data posted by our equipment. In our system the data received from transmitter unit is displayed in Thing Speak cloud and can get throughout the internet. This data can be retrieved in the form of datasets, such as Excel sheets. Based on this machine learning models are implemented.

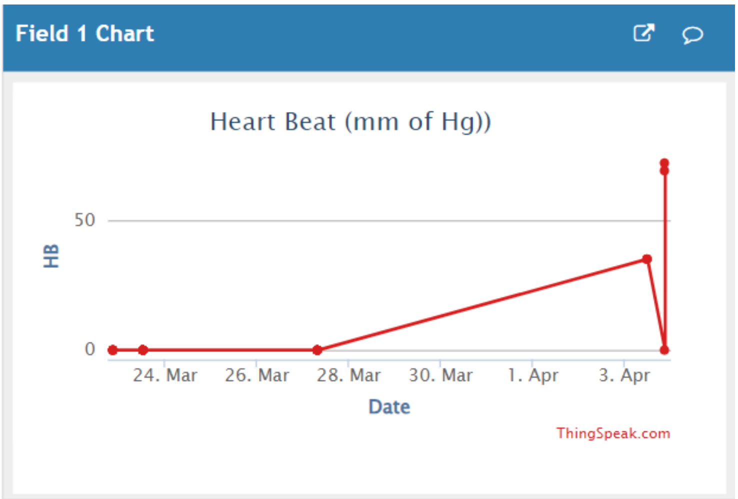


Figure A: Heart Beat monitoring

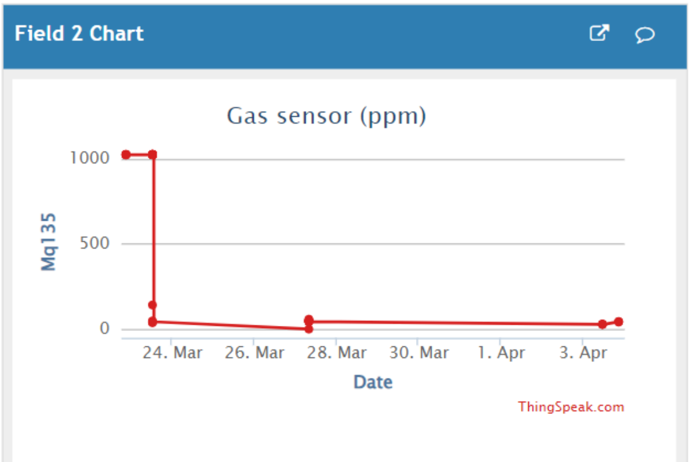


Figure B: Gas monitoring

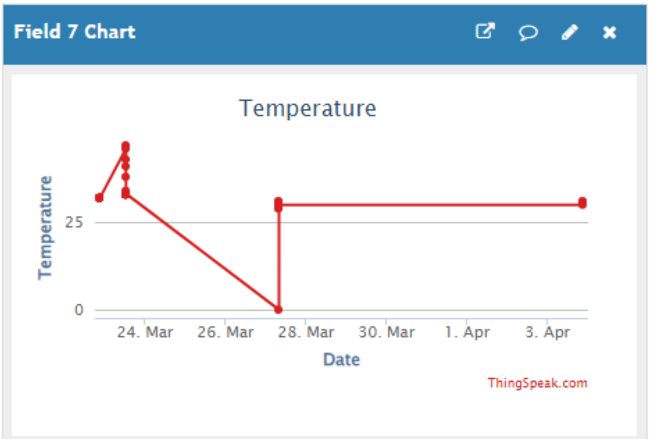


Figure C: Temperature Monitoring in Thing Speak

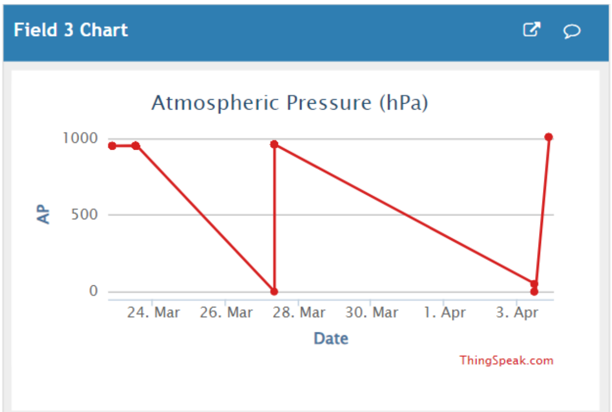


Figure D: Pressure Monitoring in Thing Speak

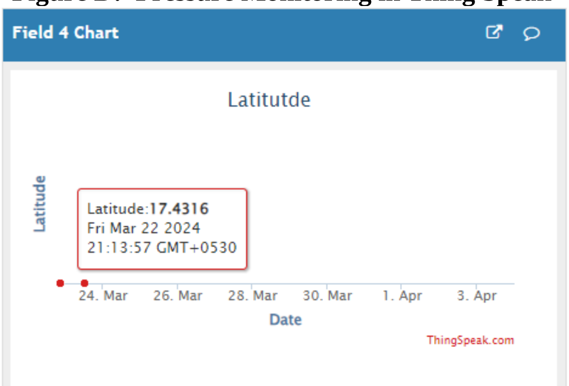


Figure E: Latitude Data

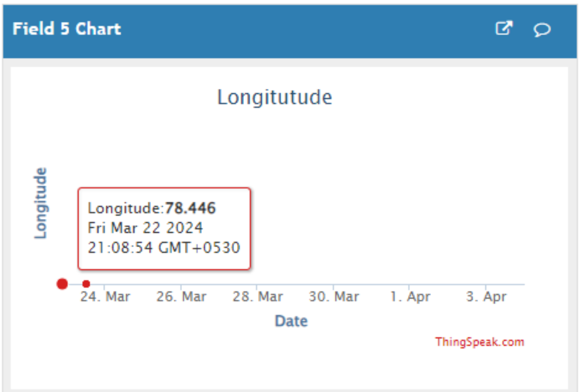


Figure F: Longitude Data

Figure 13: Thing Speak data monitoring graphs

Figure 13 displays different data visualizations collected from the sensors including information about heart rate, gas levels, atmospheric conditions, and GPS coordinates.

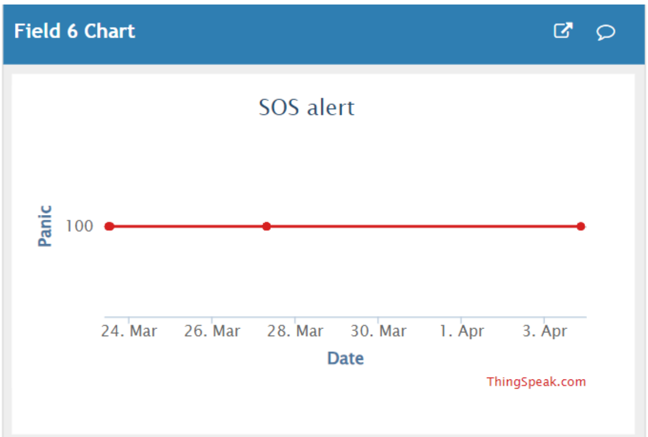


Figure 14: SOS alert system

CONCLUSION

This system designed with IoT based devices and development with ML algorithms. This paper is detailed about safety of mining workers in mining industry, and applied with technical knowledge. It is a modern safety solution for mining workers to escape from mining environment obstacles. This model has two modules such as transmitter and receiver units. It is implemented with modern tools like Thing Speak, ML with IoT. During this paper evolving our team put executive ethics and realized the importance of collaborative work and unity. This solution can be accessed at various levels of multiple sectors for eternal leaning. The future improvements are increasing battery life, predicting hazardous situation before entering mining locations, develop an app which is accessible to individual miner, to track miner's health and provide first aid guidelines.

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